Bubbles and Acoustic Communications Experiment (SPACE08): Acoustical and Physical Characteristics of Diffuse Bubble Plumes

Svein Vagle
Ocean Sciences Division
Institute of Ocean Sciences
9860 West Saanich Road
P.O. Box 6000
Sidney, BC, V8L 4B2
Canada
phone: (250) 363-6339   fax: (250) 363-6798   email: Svein.Vagle@dfo-mpo.gc.ca

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LONG-TERM GOALS

The scientific rationale for SPACE is that even though reliable underwater acoustic communication is central to the Navy's vision and Concept of Operations (CONOPS) for the future, and while significant progress in communications system development has been made in the last 15 years, current techniques fall far short of what is needed in terms of the data rates, the range of environments and operating conditions, and levels of covertness at which reliable communication links can be established. For example, communications in very dynamic environments (e.g., surface scattered environments in rough weather, communications at depth and speed for submarines) or at low SNRs as required for covert communications are areas where progress is still needed. To bridge the gap between current capabilities and future requirements, SPACE brings together a team of 10 investigators with world leading expertise in physical oceanography, underwater acoustics, signal processing, information theory and coding, practical modem development, Navy CONOPS and assets, and in the use of autonomous and distributed systems.

The main goal of this particular project is to investigate the acoustical and physical characteristics of upper ocean bubble plumes from generation to dissolution, especially as they affect the acoustical environment. In-situ and remote acoustical measurements of bubbles, turbulence, surface waves and whitecaps will be combined with ACOMMS experiments run separately by Jim Preisig (WHOI) and Grant Deane's (Scripps) α-plume investigation, so as to permit direct integration of modeling and analysis. This particular project is a collaborative effort between the Institute of Ocean Sciences (Vagle) and University of Rhode Island (David M. Farmer).

OBJECTIVES

The project objectives are to answer the following questions;

(1) how do we use forward scattered 100 and 120 kHz acoustic signals to infer the contribution of turbulence and bubbles to propagation fluctuations? Conversely, how do we exploit the propagation measurements to separate out the natural variability due to turbulence and bubbles from ACOMMS signals of interest? Given the contribution of turbulence and bubbles, how do we characterize the resulting variability so as to allow the optimization of acoustic communications algorithms?

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14. ABSTRACT

The scientific rationale for SPACE is that even though reliable underwater acoustic communication is central to the Navy?s vision and Concept of Operations (CONOPS) for the future, and while significant progress in communications system development has been made in the last 15 years, current techniques fall far short of what is needed in terms of the data rates, the range of environments and operating conditions, and levels of covertness at which reliable communication links can be established. For example, communications in very dynamic environments (e.g., surface scattered environments in rough weather, communications at depth and speed for submarines) or at low SNRs as required for covert communications are areas where progress is still needed. To bridge the gap between current capabilities and future requirements, SPACE brings together a team of 10 investigators with world leading expertise in physical oceanography, underwater acoustics, signal processing, information theory and coding, practical modem development, Navy CONOPS and assets, and in the use of autonomous and distributed systems.

15. SUBJECT TERMS

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(2) How does surface turbulence (including Langmuir circulation) and bottom boundary layer turbulence influence the distribution of bubbles in the water column, with corresponding effects on propagation?

(3) How does the bubble size distribution depend on wave breaking, turbulence, Langmuir advection and bottom boundary layer turbulence?

(4) Can we use ambient noise as a surrogate for inferring acoustic characteristics of the upper ocean boundary layer? Is the acoustic intensity and spectrum of the noise source related to whitecap speed, dimensions and other properties?

APPROACH

The following measurements will be acquired in October and November 2008 at the Martha's Vineyard Coastal Observatory (MVCO) at Woods Hole Oceanographic Institution (WHOI) (The same experimental setup was prepared for deployment during the same time period in 2007, when it was aborted, at last minute, due to missing environmental permits):

To study volume acoustic fluctuations and turbulence we will use simultaneous forward propagation and backscatter measurements at 100 kHz along a 40m path (Figure 1). A 120 kHz 8-transducer scintillation system will also be deployed on two tripods along a 40m path orthogonal to the 100 kHz system path and will be used to investigate flow characteristics and the role of temperature versus velocity fluctuations in modulating the acoustical signals. Reciprocal transmissions will allow separation of scalar and vector components. The two 100 kHz sidescan sonars can be aimed towards each other for reciprocal transmissions or rotated horizontally to allow for bubble cloud imaging and Doppler analysis for measurements of the directional wave field. These acoustic wave measurements will be augmented by an array of capacitative wave gauges mounted on the MVCO tower. Two vertical 50kHz sonars located at each of the 100kHz tripods will be augmented by a separate multi-frequency backscatter system deployed by Andone Lavery (WHOI) in the center of the array, to yield profiles of the bubble clouds and local measurement of the wave spectrum (Thorpe et al., 2003). The local sound speed field will be obtained from a recording Seabird 19plus CTD. These observations will be supported by an upward-looking 300 kHz ADCP to measure the overall velocity profile, Grant Deane's (SIO) 3-D ADV at intermediate depth to measure small-scale structure, and Lavery's turbulence and *in situ* salinity measurements of the WHOI tower to measure background turbulence and density structure. The oxygen and nitrogen content (required for modeling of bubble plume evolution) will be monitored using a combination of an oxygen sensor and a gas tension device attached to the Seabird 19plus CTD mounted on one of the sonar tripods (Farmer et al., 1993; McNeil et al., 1995). We will also use our upward looking echo-sounders together with a wave following float tethered to a horizontal mooring attached to the MVCO tower (Figure 2) to map out the local bubble field at a range of temporal and spatial scales. The sensors on the wave following float will be measuring *in situ* air-fractions and bubble size distributions (Farmer et al.,1998, 2005; Vagle & Farmer, 1998) and the temperature and salinity field at two depths in the upper 1.5 m of the water column. The vertical 50 kHz echo-sounders will acquire the diffuse, resonant bubble measurements which will be interpreted in terms of vertical representative bubble spectra, measured dissolved gas concentration, and vertical velocity measurements acquired with Doppler processing of the sonar data.

Ambient sound measurements will be acquired with two broadband (40-25,000 Hz) hydrophones deployed on the 100 kHz sidescan sonar tripods.

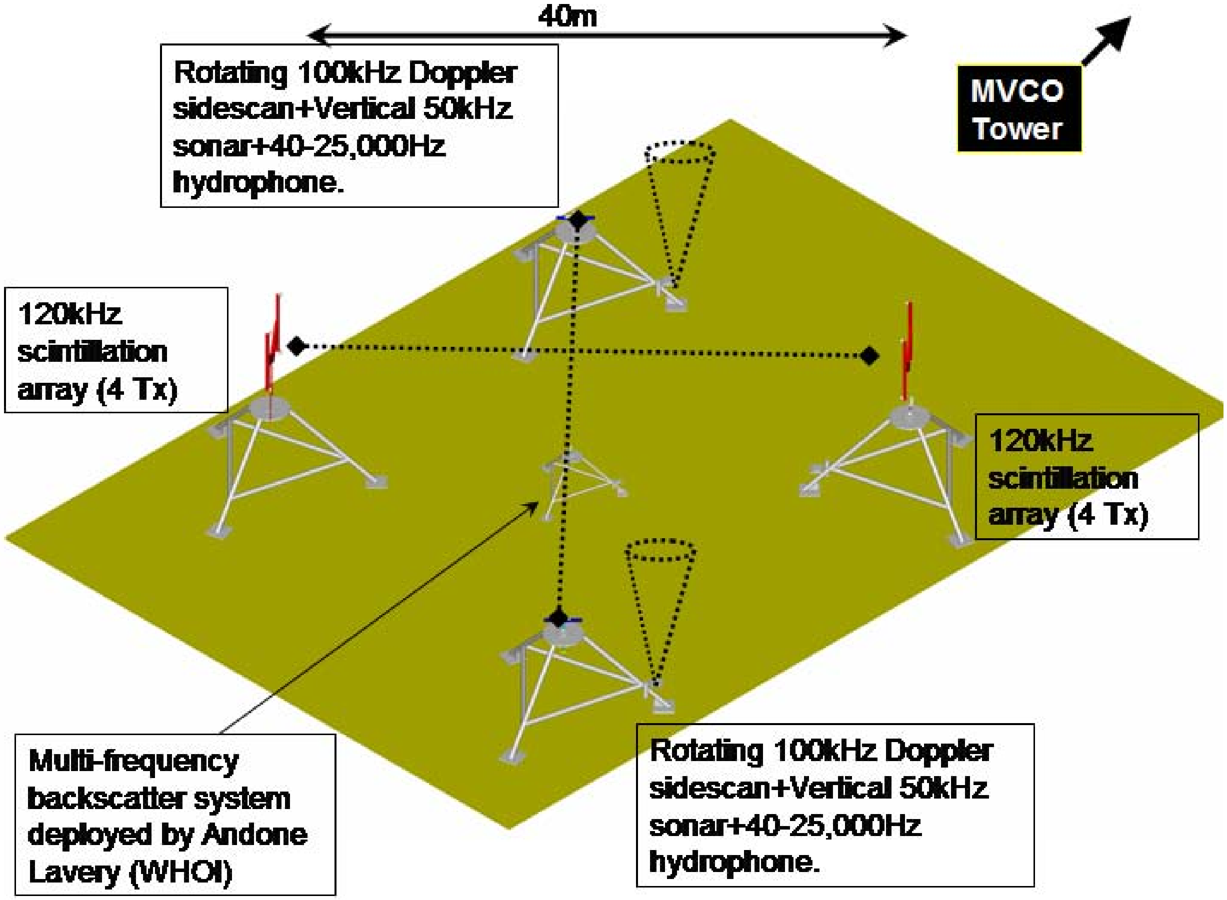

Figure 1. Three dimensional diagram showing the location of the two 100 kHz sidescan sonar, and broadband hydrophone, tripods and the two 120kHz scintillation array tripods as they will be deployed on the seafloor acoustic Doppler Current Profiler (ADCP) and a Seabird 19plus CTD will also be deployed on one of the tripods.

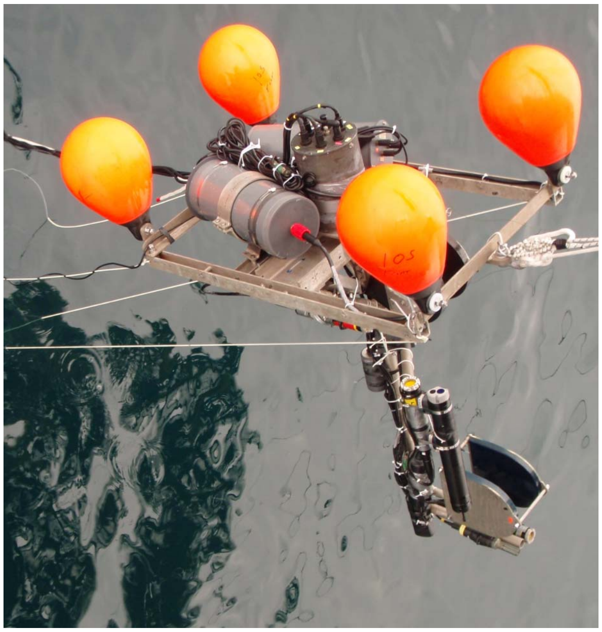

Figure 2. Surface wave following float to be used as part of the SPACE08 experiment. Sensors on the float include two acoustical resonators for measurements of bubble size distributions at 0.5 and 1.5m depths plus Conductivity and Temperature sensors and a motion sensing package. The float will be deployed from the MVCO tower using an underwater horizontal mooring.

WORK COMPLETED

All the equipment was prepared for deployment at the Graduate School of Oceanography (GSO) campus of the University of Rhode Island (URI) last September (2007). Due to the unfortunate problem with environmental permitting all the tripods had to be dismantled and sensors stored before anything was deployed. The equipment was stored for redeployment in October 2008.
The equipment is presently being assembled at GSO once again for deployment at MVCO during the first and second week of October 2008.

Progress has also been made in developing processing and analysis tools to deal with the large acoustical data set expected from SPACE08, Figure 3 shows an example of the bubble field detected with an upward pointing 120 kHz backscatter sonar deployed on a small tripod during the initial parts of the SPACE02 field experiment. The black line on top shows the surface wave field as extracted from the sonar and the light purple shows the detected bubble cloud depth for a 60 minute period when the wind speed was approximately 10 m/s. By integrating the backscatter signal over depth from the surface and down to the bottom of the the bubble layer one obtain a measure of the bubble density as a function of time. In the lower panels of Figure 3, this depth integrated backscatter cross section as well as bubble penetration depth and the e-folding depth of the backscatter cross section have been plotted against each other.

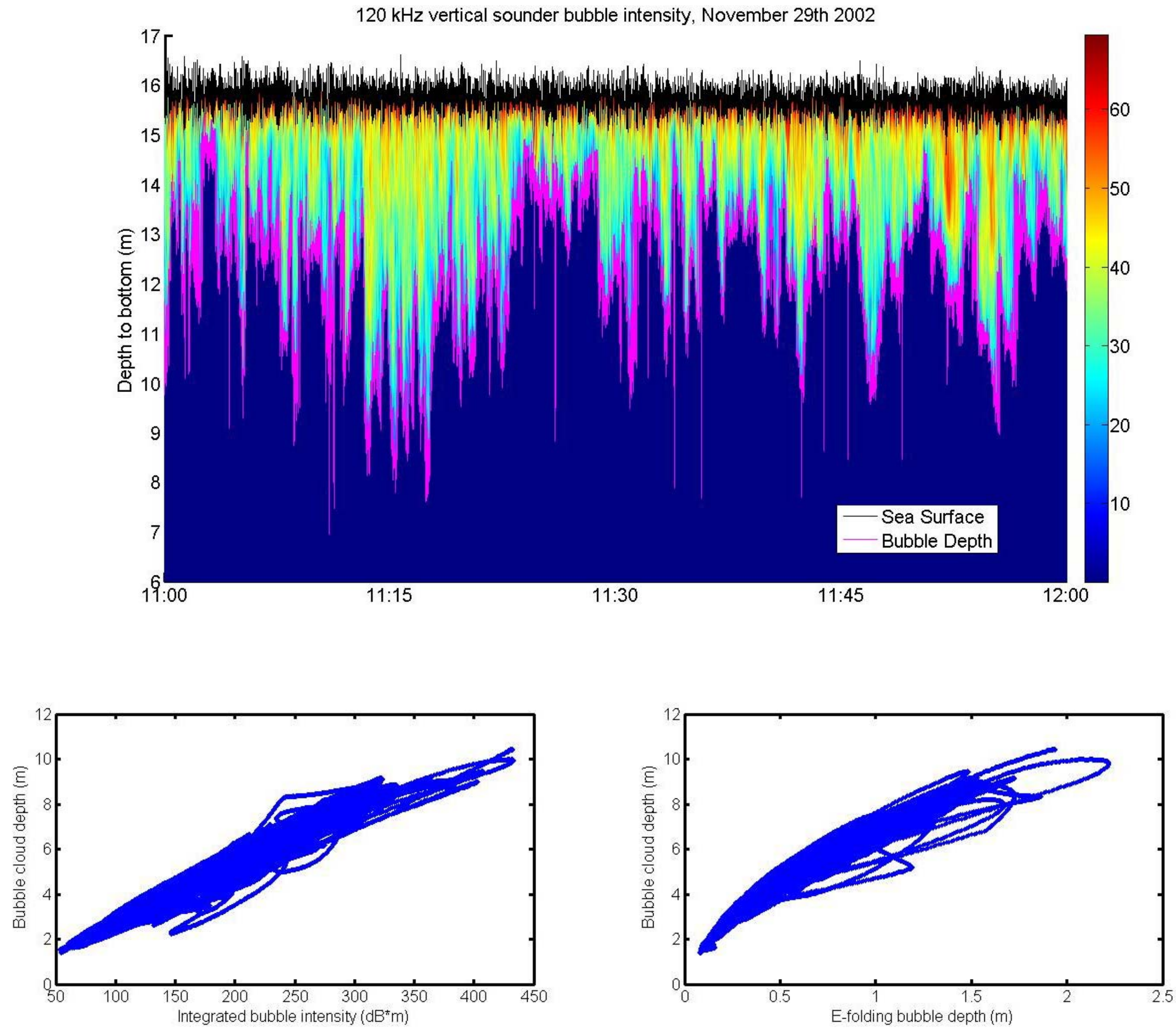

Figure 3. (Top panel) Relative backscatter cross section per unit volume of bubble field collected at MVCO during the setup period of the SPACE02 experiment. The black line shows the detected surface gravity waves and the light purple line shows the detected bottom of the bubble clouds. In the lower left panel the backscatter cross section per unit volume has been integrated over the depth of the bubble field and is plotted agains the detected bubble cloud depth. In the lower right panel the corresponding e-folding depth of the scattering cross section per unit volume is plotted against the same bubble cloud depth. The wind speed at this time was averaging 10 m/s.

RELATED PROJECTS

This project represents a component of the ACOMMS MURI project lead by Jim Preisig from WHOI. The surface following float and associated acoustical resonators were successfully deployed from R/P FLIP and R/V Kilo Moana during September 2008 as part of the first RadyO field experiment (N000140610379 & N000140710754).

REFERENCES

Farmer, D.M., S. Vagle, and A.D. Booth, 1998, A free flooding acoustical resonator for measurement of bubble size distributions, *J. Atmos. Oceanic Technol.*, 15(5), 1132–1146.

Farmer, D.M., S. Vagle, and A.D. Booth, 2005, Reverberation Effects in Acoustical Resonators for Bubble Measurements, *J. Acous. Soc. Am.*, 118, 2954-2960.

Thorpe, S.A., Osborn, T.R., Farmer, D.M., and Vagle, S.2003, “Bubble clouds and Langmuir circulation: observations and models”, *J. Phys. Ocean*. **33** 2013-2031.

Vagle, S., and Farmer D.M., 1998, A comparison of four methods for bubble size and void fraction measurements, *IEEE J. of Oceanic Engineering*, 211-222.